TENNESSEE GROUND-WATER QUALITY

By Robert E. Broshears

U.S. Geological Survey Open-File Report 87-0753

DEPARTMENT OF THE INTERIOR

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FOREWORD

This report contains summary information on ground-water quality in one of the 50 States, Puerto Rico, the Virgin Islands, or the Trust Territories of the Pacific Islands, Saipan, Guam, and American Samoa. The material is extracted from the manuscript of the *1986 National Water Summary*, and with the exception of the illustrations, which will be reproduced in multi-color in the *1986 National Water Summary*, the format and content of this report is identical to the State ground-water-quality descriptions to be published in the *1986 National Water Summary*. Release of this information before formal publication in the *1986 National Water Summary* permits the earliest access by the public.

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Ground-Water Quality

Ground water, suitable for most uses, is potentially available in nearly all communities in Tennessee (fig. 1). About 51 percent of the State's population depends on ground water for household use. Industrial consumption averages 190 Mgal/d (million gallons per day) (U.S. Geological Survey, 1985, p. 391). Most ground water is withdrawn in the western one-quarter of the State, where confined sand aquifers yield ample supplies of water satisfactory for most uses. Interest is increasing in additional development of ground-water resources in middle and eastern Tennessee. These areas are underlain primarily by carbonate aquifers that differ in yield and water quality.

Where adequate supply exists, water quality is seldom a limiting factor on use. However, concentrations of dissolved solids and iron are large in some ground water. As in most areas of the country, the major focus of water quality is contamination induced by waste disposal and other human activities. These problems are localized at hazardous-waste sites, landfills, and spill areas. Tennessee has seven hazardous-waste sites on the National Priorities List (NPL) (U.S. Environmental Protection Agency, 1986c), six of which pose some threat to local ground-water use. At several of these sites, organic chemicals, including industrial solvents and residues from pesticide manufacturing, are of concern. The problems at these sites are being addressed under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Of the State's 13 non-federal disposal sites regulated under the Resource Conservation and Recovery Act (RCRA), 12 show evidence of ground-water contamination (Dwight Hinch, Tennessee Department of Health and Environment, written commun., 1988). In addition to these sites, the State is the site of developmental efforts in atomic energy at Oak Ridge Reservation, Tennessee, where radioactive and chemically hazardous wastes have contaminated local ground water (Geraghty and Miller, Inc., 1985). In addition, six sites at three facilities were identified by the U.S. Department of Defense (DOD) as requiring response action in accordance with CERCLA. Other sources of contamination in urban communities include leaking underground storage tanks and domestic septic tank systems.

Water-quality problems will remain a major concern in Tennessee as urbanization and industrialization increase (see population distribution in fig. 1*B*). This concern is manifest within the State government, where new legislation and administrative structures have been designed to address problems of ground-water quality.

WATER QUALITY IN PRINCIPAL AQUIFERS

Tennessee's ground-water resources occur in nine regional aquifers: the alluvial, the Tertiary sand, the Cretaceous sand, the Pennsylvanian sandstone, the Mississippian carbonate, the Ordovician carbonate, the Knox, the Cambrian-Ordovician carbonate, and the crystalline rock aquifers (figs. 2*A*,*B*). The physical characteristics of these aquifers have been described previously (U.S. Geological Survey, 1985, p. 391–396).

Chemical constituents and physical properties of ground water in Tennessee generally do not exceed the national drinking-water standards (U.S. Environmental Protection Agency, 1986a,b). Water in sand aquifers is commonly soft and slightly acidic, with small concentrations of dissolved solids. In several regions, increased iron and sulfate concentrations result from the dissolution of pyrite and other iron- and sulfur-bearing minerals. In carbonate aquifers, geochemical interactions cause increases in hardness and alkalinity along most flow paths. Saline water occurs in deep aquifers or within poorly developed solution openings in flat-lying carbonate rocks. Nitrate is seldom a problem in Tennessee's ground waters.

BACKGROUND WATER QUALITY

A graphic summary of selected water-quality variables compiled from the U.S. Geological Survey's National Water Data Storage and Retrieval System (WATSTORE) is presented in figure 2*C*. The summary is based on dissolved-solids, hardness, nitrate plus nitrite (as nitrogen), and iron analyses of water samples collected from 1965 to 1985 from the principal aquifers in Tennessee. Percentiles of these variables are compared to national standards that specify the maximum concentration or level of a contaminant in drinking-water supply as established by the U.S. Environmental Protection Agency (1986a,b). The primary maximum contaminant level standards are health related and are legally enforceable. The secondary maximum contaminant level standards apply to esthetic qualities and are recommended guidelines. The primary drinking-water standards include a maximum concentration of 10 mg/L (milligrams per liter) nitrate (as nitrogen), and the secondary drinking-water standards include maximum concentrations of 500 mg/L dissolved solids and 300 μg/L (micrograms per liter) iron.

Alluvial Aquifer

The alluvial aquifer underlies the flood plain of the Mississippi River and its tributaries in extreme western Tennessee (fig. 2*A*). Use of the alluvial aquifer is limited primarily to rural-domestic supplies, because in most areas of west Tennessee water of better quality is available from a deeper aquifer. Although concentrations of dissolved solids are not excessive (90 percent of the analyses are less than 500 mg/L), the calcium bicarbonate type water is very hard. Median hardness is 200 mg/L. Iron concentrations generally exceed 1,000 μg/L, and some industrial users have been forced to abandon wells in the alluvial aquifer because of iron accumulation in pipes. The alluvial aquifer is unconfined, and, therefore, susceptible to contamination from all waste sites.

Tertiary Sand Aquifer

The most extensive and productive aquifer in Tennessee is the Tertiary sand, which supplies about 190 Mgal/d to the city of Memphis. Calcium bicarbonate type water from this confined aquifer has small concentrations of dissolved solids (90 percent of analyses are less than 163 mg/L), and is generally soft (median hardness is 39 mg/L). The only major water-quality problem is a large iron concentration, which requires that the water be treated before use. The median iron concentration is 600 μg/L. There is concern, however, that leakage of contaminated water from the overlying alluvial aquifer may degrade water quality in the Tertiary sand. In addition, several hazardous-waste sites are located in recharge areas of this important aquifer (fig. 3*A*).

Cretaceous Sand Aquifer

The Cretaceous sand aquifer is an important water source in its outcrop area. The concentration of dissolved solids is smaller than 256 mg/L for 90 percent of the analyses. In general, the concentration of dissolved solids increases along the flow paths. In the downgradient confined part of the aquifer, the concentration of dissolved solids may exceed 500 mg/L; the water type changes from calcium bicarbonate to sodium bicarbonate; and iron concentrations may be excessive. In 25 percent of all analyses, the iron concentrations exceed 1,000 μg/L. In the McNairy Sand, a Cretaceous formation underlying the Memphis area, the sodium bicarbonate type water is soft, but the fluoride concentration may exceed the primary drinking-water standard of 4 mg/L (U.S. Environmental Protection Agency, 1986a).

Pennsylvanian Sandstone Aquifer

Seventeen public utilities on the Cumberland Plateau withdraw water from the Pennsylvanian sandstone aquifer, where shallow flow paths occur in interconnected fractures. Seventy-five percent of the dissolved-solids concentrations are smaller than 210 mg/L, and the median hardness is 51 mg/L. Where flow paths intercept sandstone or shale containing pyrite or other minerals rich in ferrous and sulfurous compounds, ground water may develop large concentrations of iron, sulfate, or hydrogen sulfide. No hazardous-waste sites are documented in areas served by this aquifer, but because of mining and oil and gas operations, degradation of ground-water quality has been observed.

Mississippian Carbonate Aquifer

The Mississippian carbonate aquifer, which underlies the Highland Rim of middle Tennessee, is used extensively for public drinking-water supplies. Most ground-water movement is through the relatively thick regolith and the secondary openings in the underlying rock. Concentrations of dissolved solids increase along the flow paths; the median concentration of dissolved solids is 174 mg/L. Water is generally hard (median hardness is 150 mg/L), and iron, manganese, and sulfate concentrations are large in some areas. The Mississippian carbonate aquifer has some protection from potential contamination because it is overlain by a clay-rich regolith that is 80 feet thick in some areas. In certain regions, however, the land overlying the aquifer is characterized by sinkholes. Industrial wastes, including sulfuric acid, heavy metals, and petroleum products, have been dumped into these sinkholes, and a few localized flow systems have become contaminated.

Ordovician Carbonate Aquifer

Water in the Ordovician carbonate aquifer travels primarily through fractures and solution channels, and flow systems are commonly localized. Water-quality characteristics differ and reflect local flow dynamics and geochemical conditions. Where ground-water velocities are rapid and flow paths are relatively short, the concentration of dissolved solids is generally smaller than 500 mg/L. In contrast, concentrations exceeding 1,000 mg/L are not uncommon in isolated flow cells. Calcium bicarbonate type water is common in this aquifer, where 90 percent of the analyses for hardness exceed 130 mg/L. Hydrogen sulfide gas is present in about one-fifth of all wells, indicating reducing geochemical environments. Caves and sinkholes occur in some recharge areas, rendering this aquifer locally vulnerable to infiltration by surface contaminants. Also, the Ordovician carbonate aquifer underlies the Nashville metropolitan area, where numerous septic tanks have caused widespread degradation of shallow ground water.

Knox Aquifer

The Knox aquifer of middle Tennessee is a deep-lying limestone and dolomite aquifer. Currently, public supplies are not obtained from the Knox, but small yielding private wells have been drilled in areas where no alternative water source is available. Where the Knox aquifer is shallow, concentrations of dissolved solids are smaller than 600 mg/L. However, most of the Knox is deeper than 700 feet, and the water is very mineralized (the median dissolved-solids concentration is 1,160 mg/L). Where concentrations of dissolved solids exceed 1,000 mg/L, the water type is sodium chloride or sodium sulfate. Fluoride concentration exceeds 2.0 mg/L in many areas. Owing to its relative isolation and poor water quality, the Knox, at depths greater than 3,000 feet, has been used for deep-well injection of industrial wastes. However, confining layers between the lower and upper Knox are not well defined, and the potential may exist for contamination of drinking-water supplies.

Cambrian-Ordovician Carbonate Aquifer

Within the Cambrian-Ordovician carbonate aquifer, water occurs in solution openings in carbonate rocks and in fractures and bedding planes in sandstone and shale. More than 75 communities use this aquifer for their public water supply. Most withdrawals are from springs or wells less than 300 feet deep. In these shallow systems, concentrations of dissolved solids seldom exceed 500 mg/L, although the water is commonly very hard (median hardness is 190 mg/L). The combination of complex rock structure and rapid ground-water movement renders this aquifer particularly vulnerable to contamination.

Crystalline Rock Aquifer

Little information is available on water quality in the crystalline rock aquifer. Flow is localized in the thick regolith and in the bedrock fractures beneath mountainous terrain (Zurawski, 1979). The few water-quality data available indicate that the ground water is very soft and has small concentrations of dissolved solids.

EFFECTS OF LAND USE ON WATER QUALITY

Ground-water quality has been degraded in some areas of Tennessee because of waste disposal. The State's CERCLA and RCRA sites, areas of contaminated ground water, and the distribution of wells that yield contaminated water and municipal landfills are shown in figure 3. The U.S. Geological Survey has conducted hydrogeologic and geochemical investigations at several of these sites and continues to be active in research on the transport and fate of hazardous constituents in the subsurface environment.

Hazardous-Waste Sites

Several dump sites in the Memphis area contain hazardous wastes (Parks and others, 1982; Graham, 1985). One of these landfills, the North Hollywood Dump in Shelby County (fig. 3*A*, site A), is the State's top-ranked CERCLA site. It is also the study area for a U.S. Geological Survey project investigating the mobility of hazardous organic compounds in an alluvial aquifer. The contaminants of major concern at the North Hollywood Dump are organochlorine pesticides, including lindane, heptachlor, and chlordane. Hazardous-waste sites in the Memphis area contribute toxic leachates to the unconfined alluvial aquifer. In most places, a clay confining layer separates this aquifer from the Memphis Sand, a Tertiary sand unit that provides the drinking water for the city. The potential for contaminated water from the alluvial aquifer to enter the Memphis Sand is a primary concern.

Two other pesticide-laden waste sites that are also on the NPL are located in outcrop areas of the Tertiary sand aquifer. At Gallaway Pits in Fayette County (fig. 3*A*, site B), chlordane, endrin, and lindane have been detected in shallow ground water. In Hardeman County, localized contamination of the aquifer has forced the abandonment of 13 private drinking-water wells (fig. 3*A*, site C). At this site, low-molecular-weight organic solvents are migrating faster than a plume of organochlorine pesticides. Apparently, the transport of pesticides is being retarded because of sorptive interactions with the aquifer matrix. This site was the study area for two investigations by the U.S. Geological Survey (Rima and others, 1967; Sprinkle, 1978). Creosote, pentachlorophenol, and other phenolic wastes have contaminated local ground water at a CERCLA site near Jackson (Madison County), Tennessee (fig. 3*A*, site D). In Gibson County (fig. 3*A*, site E; fig. 3*B*, site 1), lagoons and landfills serving an Army munitions plant have leaked, resulting in ground-water contamination by trinitrotoluene and several heavy metals.

Two hazardous-waste sites are located in the recharge area of the Mississippian carbonate aquifer. In Lawrence County (fig. 3*A*, site F), a metal-plating company has contaminated local ground water with chromium and nickel, and in Wayne County (fig. 3*A*, site G), polychlorinated biphenyls have been detected in monitoring wells near a waste-disposal site.

Hazardous-waste sites that may affect the Ordovician carbonate aquifer include a disposal area for organic solvents in Williamson County (fig. 3*A*, site H) and a municipal dump in Marshall County (fig. 3*A*, site I). The U.S. Geological Survey is conducting an investigation at the Williamson County site, where several domestic wells may be threatened. The site in Marshall County has been placed on the NPL. Situated in an abandoned limestone quarry, this dump accepted industrial wastes, including paint, pickling liquor, and wood-product residues.

In northwest Rutherford County (fig. 3*B*, site 3), waste oils and solvents dumped into sinkholes have contaminated water in the Ordovician carbonate aquifer supplying domestic wells. Organic constituents, including trichloroethylene and other chlorinated hydrocarbons, were detected in 29 of 44 samples from local wells and springs. Twenty-seven private wells were closed, and a public water system was extended to the affected households.

At Oak Ridge Reservation (fig. 3*A*, site J; fig. 3*B*, site 4), radionuclides, heavy metals, nitric acid, and various organic compounds were discharged into waste ponds or buried underground (Geraghty and Miller, Inc., 1985). The distribution of these constituents in local ground water is being investigated by several public and private agencies, including the U.S. Geological Survey (Pulliam, 1985).

Deep-well injection of industrial wastes continues in Maury County (fig. 3*A*, site K) and Humphreys County (fig. 3*A*, site L). These wastes, which include inorganic acids and some organic compounds, are injected into the lower part of the Knox aquifer. Although carbonate rocks in this formation have the capacity to neutralize acidic wastes, uncertainties concerning flow paths within the Knox and the integrity of well casings have caused some concern about potential contamination of drinking-water sources at shallower depths in the area.

As of September 1985, 83 hazardous-waste sites at 6 facilities in Tennessee had been identified by the DOD as part of their Installation Restoration Program (IRP) as having potential for contamination (U.S. Department of Defense, 1986). The IRP, established in 1976, parallels the U.S. Environmental Protection Agency (EPA) Superfund program under CERCLA of 1980. EPA presently ranks these sites under a hazard ranking system and may include them in the NPL. Of the 83 sites in the program, 30 sites contained contaminants but did not present a hazard to the environment. Six IRP sites at three facilities (fig. 3*A*) were considered to present a hazard significant enough to warrant response action in accordance with CERCLA. Remedial action at three of these sites has been completed under the program. The remaining sites were scheduled for confirmation studies to determine if remedial action is required.

Other Sources of Contamination

Other sources of ground-water contamination include leaking underground storage tanks and domestic septic systems. An average of two reports per week are being filed with the Tennessee Division of Groundwater Protection, the office that responds to suspected leaks from underground storage tanks (Robert Hall, Tennessee Division of Ground Water Protection, oral commun., 1986). Widespread use of septic fields for domestic sewage disposal in several middle Tennessee communities has led to ground-water degradation. Ground water in the cities of Nashville, Hendersonville (Sumner County), La Vergne (Rutherford County), and Mt. Juliet (Wilson County) has been particularly affected (D. Elmo Lunn, Tennessee Division of Water Quality Control, written commun., 1981), as has ground water in Hamilton County (Tennessee Department of Health and Environment, 1986a).

Acid mine drainage in certain areas of the Cumberland Plateau has degraded local ground water. In well water near mines, lower pH values and increased concentrations of heavy metals have been detected (D. Elmo Lunn, Tennessee Division of Water Quality Control, written commun., 1981). Large sulfate concentrations and iron precipitation at springs are also common. Elsewhere, unplugged boreholes, drilled for zinc exploration, in the Central Basin may provide pathways for migration of water from the very mineralized Knox aquifer to the Ordovician carbonate aquifer.

Potential for Water-Quality Changes

Tennessee faces continuing challenges to its ground-water resources. These challenges result from increasing urbanization, industrialization, and demand for larger quantities of clean water.

Ground-water use throughout the State has increased steadily during the past century. In the Memphis area, the potentiometric surface has declined 100 feet in the Memphis Sand, the upper unit of the Tertiary sand aquifer. Intensive pumping from this aquifer has increased the hydraulic gradient and has accelerated recharge from the overlying alluvial aquifer by leakage through localized confining beds. Water quality in the alluvial aquifer is inferior, and toxic constituents are present near several hazardous-waste sites. As the demand for water increases, it is important that water quality within these two aquifers be monitored carefully, and that the hydraulic relations between the two units be better defined. A report addressing the potential for leakage among the principal aquifers in the Memphis area was published by the U.S. Geological Survey (Graham and Parks, 1986).

In middle and eastern Tennessee, continuing development and decreasing availability of Federal funds for surface-water treatment plants will increase the demand for ground-water supplies. Throughout areas of Tennessee where carbonate aquifers are the predominant water-supply source, sinkholes and caves provide rapid flow paths for the transport of contaminants into these aquifers. Moreover, such features create complex flow paths that are difficult to predict. Disposal of domestic wastes by septic systems is widespread and will continue to threaten the quality of shallow ground water in many areas. Wells may be drilled deeper in attempts to find cleaner water; however, deeper aquifers may produce water of inferior quality because of larger concentrations of dissolved solids. Also, deeper aquifers are more costly to develop as principal water supplies. Finally, if deep-well injection continues as a method of industrial waste disposal, questions of potential contamination of both shallow and deep aquifers will remain.

GROUND-WATER-QUALITY MANAGEMENT

The State of Tennessee recognizes the importance of ground water and has provided for the protection of this resource through the Tennessee Department of Health and Environment. Within this Department, the Division of Ground Water Protection provides general oversight and technical assistance for the State's efforts in areas related to ground-water quality. Drillers have been licensed since 1963 and are required to file reports for each well constructed. As needed, the Division of Ground Water Protection inspects new wells and performs limited water-quality analyses. The Division administers the State's program for control of leaking underground storage tanks and regulates the use of underground injection wells. Subsurface sewage disposal systems are also regulated by this agency.

The Division of Solid Waste Management administers the State's RCRA program and regulates all forms of solid-waste disposal. The Division of Superfund oversees the State's CERCLA-related activities. In addition to the seven sites on the NPL, the Division of Superfund has nominated three sites for the Federal program. These sites are located in Wayne, Shelby, and Hickman Counties, and are shown as "other" sites in figure 3*A*. It also has cataloged 253 sites that "pose or may reasonably be anticipated to pose a danger to public health, safety, and environment" (Tennessee Department of Health and Environment, 1986b). These sites, which were selected from an original list of 862 nominees, compose the "State Superfund Eligible Sites List." Hydrogeologic investigations and remedial activities are being conducted at many of these sites.

The Division of Construction Grants and Loans is responsible for programs addressing the impact of nonpoint sources of pollution on ground-water quality. In 1987 this Division began a series of cooperative studies with the U.S. Geological Survey to assess the effects of septic tank systems, urban runoff, and agricultural chemicals on ground-water quality.

The Tennessee Department of Health and Environment has defined two major priorities for its ground-water protection programs. The first priority is to establish an aquifer classification system. This system will define the need for water-quality protection as a function of an aquifer's potential use. Currently, aquifers may be classified as "underground sources of drinking water" if the dissolved-solids concentration is smaller than 10,000 mg/L. The second priority is to establish a statewide ground-water monitoring network. Recently, the State's Safe Growth Team received a report recommending such a network from researchers at the Center for the Management, Utilization, and Protection of Water Resources at Tennessee Technological University (Wilson and others, 1986). Specific recommendations included an initial sampling of about 200 representative wells to define water-quality profiles for each major aquifer. The samples would be analyzed for common and trace inorganic constituents and composite organic characteristics, such as total organic carbon and organic halides. Spatial and temporal variation in background water-quality patterns would be described and would be used to determine the optimal density of monitoring wells and sampling frequency. Finally, localized problems of ground-water quality would be addressed by synoptic studies featuring more intensive sampling for constituents of major local concern.

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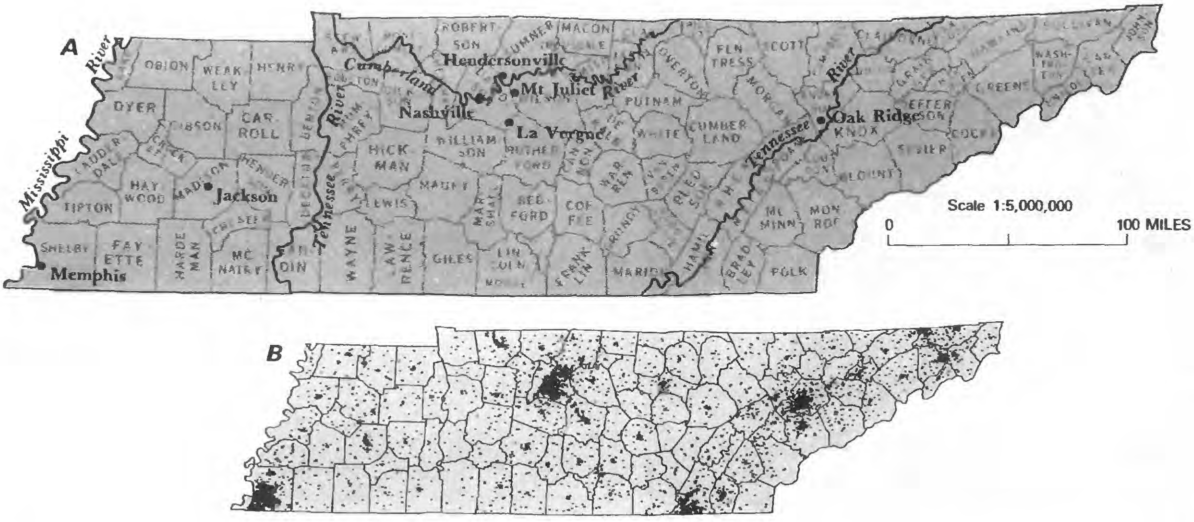

Figure 1. Selected geographic features and 1985 population distribution in Tennessee. *A*, Counties, selected cities, and major drainages. *B*, Population distribution, 1985; each dot on the map represents 1,000 people. (Source: *B*, Data from U.S. Bureau of the Census 1980 decennial census files, adjusted to the 1985 U.S. Bureau of the Census data for county populations.)

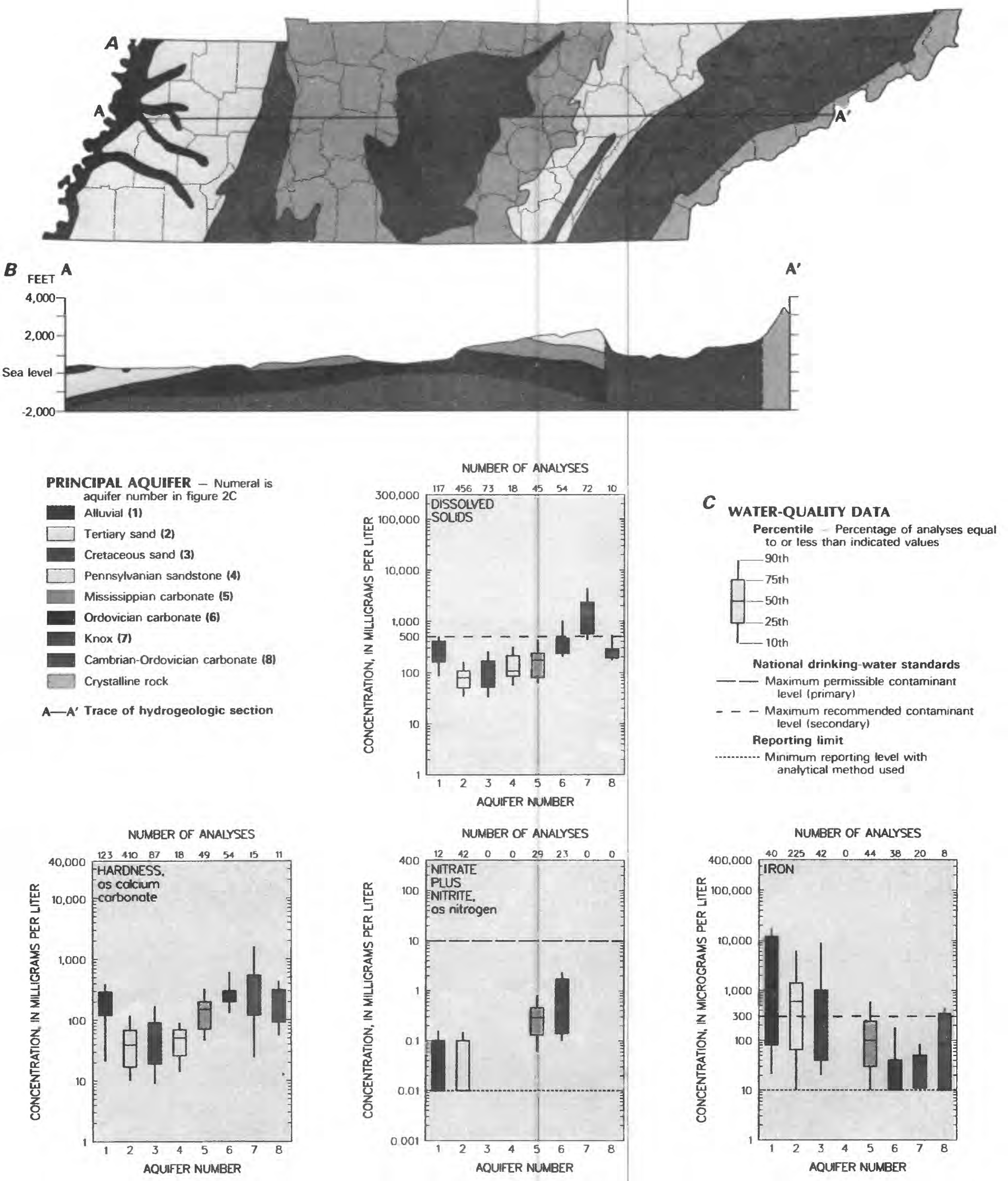

Figure 2. **Principal aquifers and related water-quality data in Tennessee.** *A*, Principal aquifers. *B*, Generalized hydrogeologic section. *C*, Selected water-quality constituents and properties, as of 1965–85. (Sources: *A*, Miller, 1974; *B*, Compiled by M.W. Bradley from U.S. Geological Survey files; *C*, Analyses compiled from U.S. Geological Survey files; national drinking-water standards from U.S. Environmental Protection Agency, 1986a,b.)

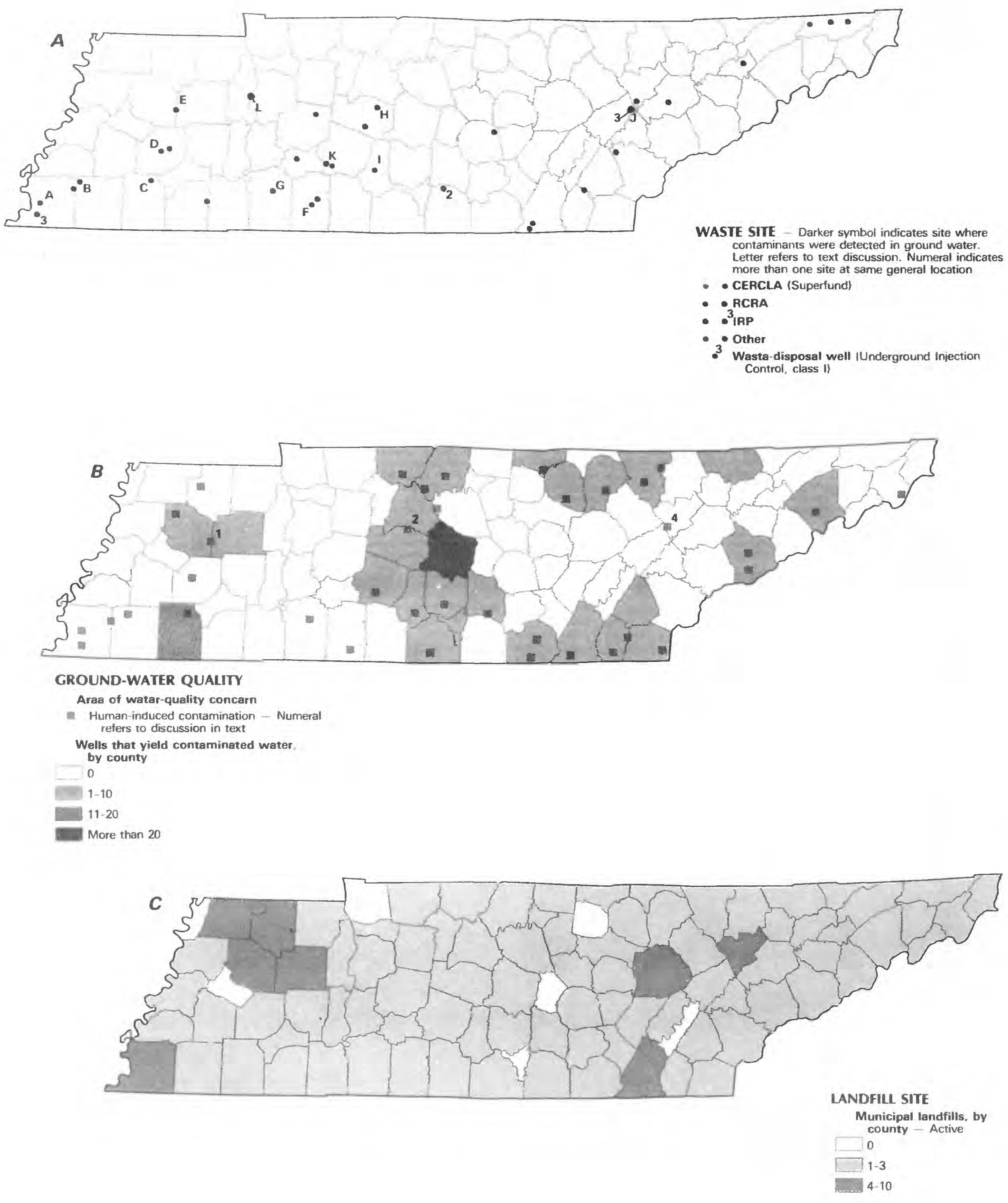

Figure 3. Selected waste sites and ground-water-quality information in Tennessee. *A*, Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites; Resource Conservation and Recovery Act (RCRA) sites; Department of Defense Installation Restoration Program (IRP) sites; and other selected waste sites, as of 1986. *B*, Areas of human-induced contamination and distribution of wells that yield contaminated water, as of 1985. *C*, Municipal landfills, as of 1986. (Sources: *A*, U.S. Environmental Protection Agency, 1986c and Tennessee Department of Health and Environment, unpublished data; U.S. Department of Defense, 1986; *B*, Association of State and Interstate Water Pollution Control Administrators, 1985; *C*, Tennessee Department of Health and Environment, unpublished data.)

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